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Data Warehouses as Tools in Supporting Decision-Making Processes in Management

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Abstract:

Purpose: *The purpose of this article is to analyse the role of data warehouses as a tool supporting decision-making processes in management, identify the key benefits resulting from their implementation, and indicate challenges and best practices in the effective use of data analysis systems.*
Design/Methodology/Approach*: The study is based on a literature review and analysis of the technological and organizational aspects of data warehouse implementation. It also incorporates case studies of enterprises that have successfully leveraged data warehouses to improve management efficiency and strategic decision-making. The research question is formulated as: How do data warehouses influence decision-making processes within organizations, and which operational mechanisms are most effective in improving the quality of decisions made? On this basis the following research hypothesis has been stated: the implementation of data warehouses, including the integration of data from multiple sources, the use of advanced analytical tools, and the automation of reporting processes, significantly enhances the quality of managerial decisions, thereby increasing organizational efficiency.*
Findings: *the findings of the analysis indicate that the effective implementation of a data warehouse significantly supports decision-making processes within an organization by consolidating and analysing data from various sources. This enables managers to make swift decisions based on comprehensive reports and forecasts derived from historical data. The main challenges associated with implementing a data warehouse include high implementation costs, the need to ensure data consistency and quality, and a lack of appropriate skills among employees. Best practices, such as integrating the data warehouse with Business Intelligence systems, using advanced analytical algorithms, and implementing mechanisms for automatic data updates, contribute to improving management efficiency and minimizing the risk of incorrect decisions.*

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Practical implications: *the study provides practical recommendations for organizations planning to implement or modernize data warehouses to improve the quality of decision-making processes. Utilizing modern analytical technologies such as big data and artificial intelligence enables more precise and dynamic decision-making. Regular employee training in data analysis and optimizing ETL processes can further enhance the efficiency of data warehouses.*
Originality/value: *The article also emphasizes the need for further research on the role of modern technologies in data integration and their impact on innovative organizational management models.*

Keywords: *Data warehouses, decision-making processes, management.*

JEL codes: *C8, D2, D81.*

Paper type: *Research article.*

1. Introduction

The development of information technologies increasingly helps businesses become more profitable and competitive. Gaining an edge over competitors requires companies to accelerate decision-making processes so they can quickly respond to changes. A key factor in speeding up decision-making is having the right information available at the right time and in an easily accessible format.

Modern enterprise management systems contain data that can provide the necessary information for decision-making. However, in most companies, this data is scattered across various systems, platforms, and locations, making it nearly impossible to ensure data integrity and access within a reasonable timeframe.

Modern organizations operate in a dynamic business environment that requires quick and effective decision-making based on reliable data. In this context, data warehouses play a key role as tools supporting decision-making processes in management. These are specially designed IT systems that integrate, store, and analyse large datasets from various sources. As a result, they provide organizations with access to consolidated, historical, and current information essential for making informed business decisions.

Data warehouses differ from traditional databases in that they are optimized for analysis and reporting rather than real-time transaction processing. Their architecture enables efficient processing of large data volumes and aggregation, which facilitates identifying trends, patterns, and relationships across various aspects of a company's operations. To provide essential information for decision-making, data warehouses are designed to support decision-making processes.

Technological advancements have made it possible for almost any organization to create a data warehouse that delivers reliable information on time for informed decision-making.

This article presents the basic aspects related to data warehouses, their structure, the benefits of their implementation, and their impact on decision-making processes in management. We will also examine the challenges associated with building and maintaining such systems and the best practices for their implementation.

2. The Essence of an Information System in Decision-Making

An information system is an integrated set of tools, technologies, and procedures used for collecting, processing, storing, and disseminating information within an organization. Its primary goal is to support decision-making processes by providing current and precise data (Fehner, 2007, p. 127). Through their application, organizations can effectively manage resources, optimize processes, and enhance their competitiveness in the market.

It is also a formal computer system that selects, provides, and integrates data from various sources to deliver necessary information in a timely manner for decision-making. An information system consists of an information technology system, a telecommunications system, and a traditional information operation system, often referred to as a "manual system" (Ciesielski, 2012, p. 20). The following types of information systems are distinguished:

- Transaction Processing Data Systems - TPS also referred to as Electronic Data Processing - EPD.
- Management Information Systems - MIS, at their current state of development are identified with Relational Data Base Management Systems (RDBMS).
- Decision Support Systems - DSS.
- Expert Systems - ES.
- Executive Information Systems - EIS; sometimes equated with Executive Support Systems - ESS, in Polish literature often referred to under the acronym: SIK.
- Artificial Intelligence Systems - AIS, often identified with Artificial Neuron Networks - ANN.
- Management Support Systems - MSS) in Polish literature often abbreviated as SWZ.
- Office Automation Systems - OAS.
- Computer Aided Designing - CAD.
- Computer Aided Manufacturing - CAM.
- Computer Aided Engineering - CAE) (Jarke, Lenzerini, Vassiliou, and Vassiliadis, 2023).

Currently, most decisions are made in situations of risk and uncertainty, where it is more difficult to predict future events without additional information (Nowosielski, 2017, p. 143). Information systems can be organized hierarchically according to the management levels in an organization:

- Operating Systems – handle daily business operations, such as sales transactions, production management, or resource monitoring. They serve as a data source for more advanced analytical systems.
- Management Information Systems (MIS) – aggregate and report data from operational systems, providing information to managers at various levels of management.
- Decision Support Systems (DSS) – use historical and current data to model scenarios and analyse decision alternatives. They utilize information provided by EIS.
- Expert systems (ES) – represent an advanced layer supporting decision-making processes through data analysis and providing recommendations based on rules and artificial intelligence (Kopczewski, 2014, p. 10).

Each of these systems plays a crucial role in management as they provide essential information and analytical tools that aid in making accurate decisions. By using them, organizations can plan their activities more effectively, manage resources better, and adapt flexibly to dynamic changes in the business environment.

The application of information systems in management processes contributes to increased operational efficiency, improved competitiveness, and minimized decision-making risks. Their integration and development are key to the success of organizations in a modern, complex business environment.

3. Relationships between Information Systems

Relationships between information systems play a crucial role in managing an organization because they enable a smooth flow of information, data integration, and shared support in decision-making. These systems do not operate independently but are interconnected in a hierarchical, functional, and technological manner, allowing for effective management of business processes. There are several mutual relationships between information systems. The most important relationships include:

- the existence of an organized and properly functioning information flow system within an organization;
- Comprehensive computerization of the information flow in an organization;
- maintaining the sequence in designing the computerization of information flow in an organization – first, designing the information flow system, and

then adapting or customizing software and computer hardware to its needs (Golfarelli and Rizzi, 1999).

Information systems can be organized according to the hierarchy of management within an organization. At the lowest level are operational systems, which handle daily transactions and operations such as managing sales, production, or resources. These systems serve as data sources for more advanced analytical tools. The next level includes management information systems, which aggregate operational data and generate reports to support managers in decision-making.

At a higher level are decision support systems, which analyse available information, model various scenarios, and enable the evaluation of alternative solutions. The most advanced are expert systems, which utilize artificial intelligence algorithms and expert knowledge to provide recommendations and optimal solutions.

Information systems are also interconnected through data integration and information sharing. For example, data collected by operational systems is processed in data warehouses and then analysed by Business Intelligence systems. Decision Support Systems use this information for more detailed analyses and scenario simulations. Expert systems further interpret this data, providing recommendations that can be utilized in strategic planning. As a result, all these systems work together to create a comprehensive information ecosystem.

Another important aspect is the functional complementarity of information systems. Each system plays a specific role within an organization, but together they complement one another, creating a cohesive environment that supports management. For example, ERP systems, which manage organizational resources, can collaborate with CRM systems focused on customer service (Parys, 2018, p. 666).

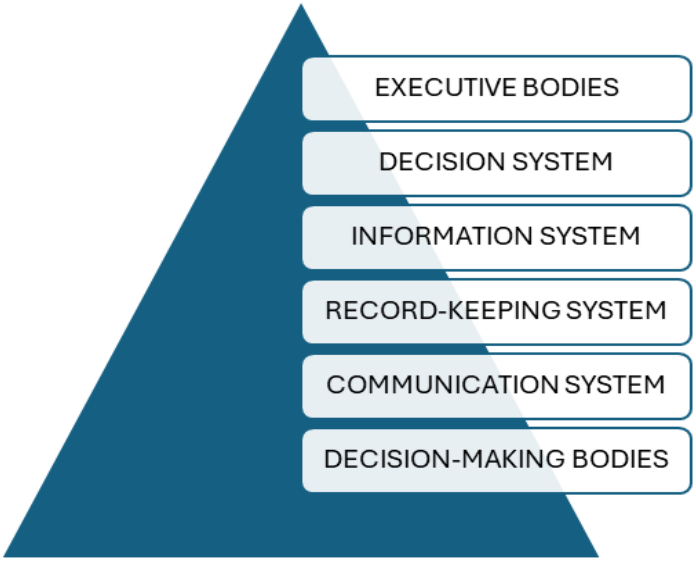
The integration of these systems enables a better understanding of customer needs and more efficient relationship management (Dziembek, 2021, p. 189). Similarly, Business Intelligence (BI) systems, which process large volumes of data and generate reports, provide critical information to decision support systems that use it to model various action scenarios. The components of BI are illustrated in the figure below.

Technological integration of information systems is another significant factor influencing their mutual relationships. Modern organizations increasingly implement advanced solutions such as cloud computing, artificial intelligence, and the Internet of Things to ensure seamless information flow between systems. This approach enables faster data analysis, improved process automation, and flexibility in adapting to changing market conditions. Considering the scope and techniques of information system analysis, the decision-making cycle phase should include the following processes, as illustrated in Figure 2.

Figure 1. *Business Intelligence elements*

Source: *N. Halder, Mastering Business Intelligence: Comprehensive Guide to Concepts, Components, Techniques, and Examples, https://medium.com/analysts-corner/mastering-business-intelligence-comprehensive-guide-to-concepts-components-techniques-and-7b1583014d87.*

Figure 2. *Phases of the Decision-making Process*



Source: *Kopczewski, 2014, p. 17.*

Information systems are closely interconnected and complement each other. Due to their hierarchical interdependence, data integration, functional complementarity, and modern technologies, their cooperation contributes to effective organizational

management. These relationships enable more informed decision-making, better resource utilization, and faster adaptation to the dynamic business environment.

4. The Essence of a Data Warehouse in an Organisation

One of the fundamental and most advanced systems in Polish business supporting decision-making processes is the concept of a data warehouse (Kopczewski, 2014, p. 18). According to the creator of this concept, W.H. Inmon, a data warehouse is an integrated, subject-oriented, time-variant collection of data designed to support managerial decision-making processes. Projects related to the implementation and deployment of data warehouse systems are risky and lengthy endeavours (Gorawski, 2023, p. 189). Below is an explanation of what a data warehouse is.

Figure 3. *What Is A Data Warehouse?*

Source: *Czym jest hurtownia danych? Definicja, komponenty, architektura, SAP.*

The goal of a data warehouse is to provide users, particularly decision-makers, with quick access to data. To achieve this goal, a data warehouse should meet several conditions:

a. data must be collected in a way that the essence of the information is not lost, even for business reasons.
b. access to information should take place based on transparent rules, while the system's supply of updated data must occur within a timeframe that does not undermine the purpose of the decision-support system.
c. the waiting time for data should be shorter than the time needed to make a decision.
d. data warehouse users should be able to perform complex analyses (e.g., competitor analysis) independently, without the help of IT specialists.
e. the most important issue is the cost of the system, which cannot be greater than the profits that will be achieved as a result of its implementation (Kopczewski, 2003).

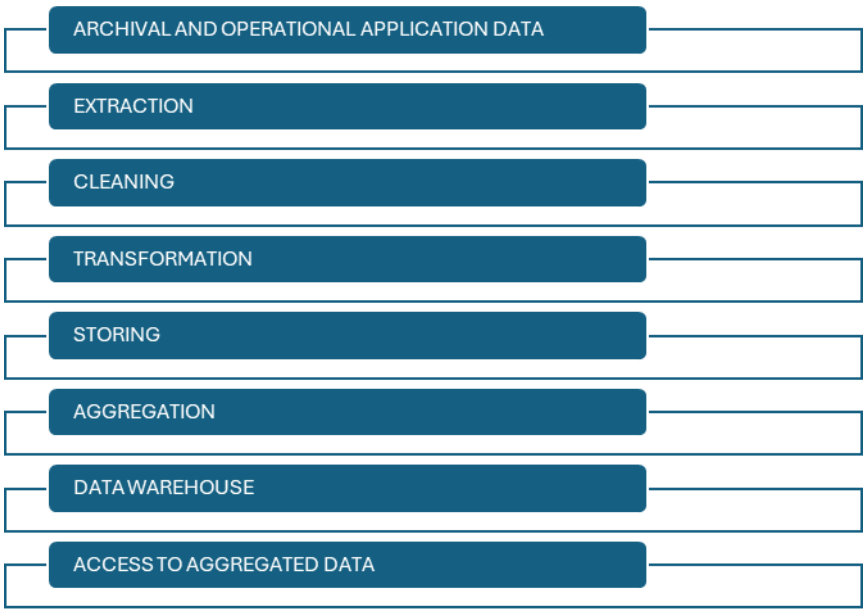
A data warehouse is a specialized database system that differs from traditional transactional systems based on operational data. Its main feature is the long-term storage of data, enabling analysis over a broader time horizon. This system is optimized for handling complex analytical queries, allowing managers and analysts

to efficiently extract valuable insights. Data in a warehouse comes from various sources, but its integration ensures consistency and uniformity.

An important category also includes historical data, which contains both detailed information and aggregated summaries about the past. Another group consists of materialized aggregates, which are pre-calculated values that facilitate analysis in various contexts and levels of detail.

Complementing these are metadata, which describe the structure of the data warehouse, data sources, and aggregation methods, enabling effective data management and interpretation in the decision-making process. Within a data warehouse, various types of information are stored to support analytical processes. These include elementary data, so current and processed copies of information obtained from operational databases. The lifecycle of data in a warehouse is illustrated in the accompanying figure.

Figure 4. *Lifecycle of Data*



Source: *Poe, Klauer, and Brobst, 2000.*

Data warehouses play a crucial role in the organizational structure, providing access to consolidated, unified, and historical data that support decision-making processes at various management levels. Their place in the organization depends on the scope of functions they perform and the way they are integrated with other IT systems.

A data warehouse is a central component of an organization's information infrastructure, connecting various data sources such as operating systems, ERP systems, CRM systems, or e-commerce platforms. It serves as a repository where

both historical and current data are stored, providing the ability for advanced analysis and reporting.

In the organizational structure, data warehouses are utilized by various units and management levels. For the management team, they serve as a foundation for making strategic decisions, enabling trend analysis, forecasting, and optimizing business operations. The finance department uses them to monitor financial performance, analyse costs, and predict revenues.

Meanwhile, operational departments such as sales, marketing, and logistics leverage data warehouses to analyse the effectiveness of their activities, segment customers, and optimize supply chain and production processes.

In large organizations, the structure of data warehouses can include both centralized and distributed systems. A centralized data warehouse integrates all information in one location, ensuring consistency and uniformity of data. On the other hand, distributed data warehouses can be tailored to the specific needs of individual departments or business units. In some cases, thematic data warehouses are also used, focusing on specific areas of activity, such as sales analysis or customer behaviour.

Operational processing systems are used in the daily activities of militarized organizations within information systems. These include OLTP (On-Line Transaction Processing) systems, which are specifically designed for operational tasks related to organizational activities and optimized for processing small amounts of data (Kopczewski, 2023). The database of such systems stores only current information about most objects (Reddy *et al.*, 2010, p. 2865).

The data in the database is updated continuously in real-time. Historical data is usually stored on separate media and is not made available in real-time. Such systems are only suitable for creating standard document reports that support ongoing operations.

This model of data processing does not facilitate data analysis processes or decision-support applications. To meet the needs of analytical processing and long-term storage of large amounts of static data, a new type of database (Eng. a data warehouse) was developed. Table 1 below presents the characteristics of a data warehouse.

Table 1. *Characteristics of a Data Warehouse.*

Feature	OLTP	Data Warehouse
Data detail	High	Medium or Low
Data Access Mode	Read and Write	Read Only
Data Consolidation	Low	High
Data Repetition	High	Low

Frequency of Data Operations	Very High	Medium or Low
Data Timeliness	Very High	Medium or Low
Time Horizon	Very Short or Short	Long (historical data)
Data Size	MB, GB	GB, TB
Number of Records Processed per Operation	Tens	Millions

Source: *Poe, Klauer, and Brobst, 2000.*

A comparison of OLTP (Online Transaction Processing) systems and data warehouses reveals significant differences between these technologies, which are tailored for distinct purposes and methods of processing information within an organization. OLTP systems are characterized by high data granularity and the ability to simultaneously read and write information.

Their primary function is to support current business operations, such as processing sales transactions, managing inventory, or handling financial operations. Due to their nature, OLTP systems handle relatively small volumes of data (megabytes or gigabytes), but the number of operations performed on this data is very high, with each operation typically processing a small number of records. The timeliness of data in OLTP systems is crucial, so the information stored is short-term, ensuring real-time access to the most up-to-date data.

Data warehouses, on the other hand, have a distinct nature and are primarily designed for analysing historical data and supporting decision-making processes. Unlike OLTP systems, data warehouses are optimized for read operations, with new information being written automatically at specific intervals.

Data in warehouses comes from various sources and undergoes integration processes, enhancing its consistency and usefulness for analyses. These systems consolidate data extensively, meaning that information from multiple operational systems is gathered and unified in one location.

Compared to OLTP systems, data warehouses store information for longer periods, enabling trend analysis and forecasting of future events. As a result, the size of stored data is significantly larger, often reaching terabytes. Operations performed on data warehouses frequently involve processing large volumes of information - with millions of records analysed in a single operation. However, the frequency of operations is lower than in OLTP systems because analyses are conducted periodically rather than in real time.

OLTP and data warehousing systems serve different but complementary functions within an organization. OLTP provides ongoing support for transactional operations, while data warehouses enable comprehensive analysis and support decision-making processes. Both approaches are essential in data management, and their integration

allows organizations to effectively process and utilize information to optimize their operations.

5. Conclusions

A data warehouse plays a crucial role in modern management, serving as the foundation for analytical systems and decision support. By integrating, storing, and analysing large volumes of data, businesses and institutions can make better-informed decisions based on reliable historical and current information. Unlike transactional systems, data warehouses are optimized for analysis and reporting, making them invaluable tools for strategic planning, resource optimization, and market trend forecasting.

In organizations, data warehouses support various levels of management, enabling both operational performance monitoring and long-term forecasting. Their applications span a wide range of fields, including financial management, sales analysis, logistics, and customer relationship management. By ensuring uniformity and consistency of data from diverse sources, data warehouses minimize the risk of decision-making errors and enable more efficient operational activities.

One of the key conclusions from analysing data warehouses is their necessity in a dynamic business environment. Companies and institutions that implement advanced data analysis systems gain a competitive advantage through faster trend detection, cost optimization, and better alignment of strategies with changing market conditions.

Despite numerous advantages, the development of data warehouses still faces challenges related to the growing volume of data, its structure, and the need for fast and efficient analysis. In the era of cloud technologies, artificial intelligence, and big data, it is essential to further improve analytical tools and integrate data warehouses with modern solutions. Automating ETL (Extract, Transform, Load) processes, advancing machine learning mechanisms, and implementing real-time solutions are just some of the directions contemporary organizations should pursue.

Further research should focus on optimizing the structure of data warehouses, increasing their efficiency, and improving the security of stored information. It will also be crucial to understand the impact of new technologies on the development of data analysis and to adapt processing methods to the growing amount of unstructured data from diverse sources, such as social media, IoT sensors, and e-commerce platforms.

In summary, data warehouses are not only the foundation of modern management systems but also an area that requires continuous modernization and adaptation to changing technological and business conditions. Their future lies in increasing

automation, integration with advanced data analytics systems, and better utilization of artificial intelligence in the decision-making process.

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